Which Kind of Knowledge Is Suitable for Redesigning Hospital Logistic Processes?

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Abstract. A knowledge management perspective is rarely used to model a process. Using the cognitive perspective on knowledge management in which we start our analysis with events and knowledge (bottom-up) instead of with processes and units (top-down), we propose a new approach for redesigning hospital logistic processes. To increase the care efficiency of multi-disciplinary patients, tailored knowledge in content and type that supports the reorganization of care should be provided. We discuss the advantages of several techniques in providing robust knowledge about the logistic hospital process by employing electronic patient records (EPR's) and diagnosis treatment combinations (DTC's).

1 Introduction

Due to the application of information technology and the promotion of changing the structure in certain organizations, business processes need to be redesigned, an approach coined as Business Process Reengineering [1]. As changes occur in the business environment, the existing process is at risk of becoming misaligned and consequently less effective. To increase the capabilities of enterprises to learn faster through their processes, strategies have been proposed that construct knowledge management systems around processes to: (i) increase their knowledge creating capacity, (ii) enhance their capacity to create value, and (iii) make them more able to learn [2]; in other words "... knowledge management (KM) can be thought of as a strategy of business process redesign" [2]. Modelling and redesigning a business process involves more than restructuring the workflow; therefore business professionals need to learn how to describe, analyze, and redesign business processes using robust methods.

Using the KM perspective, we make distinctions between content and form of knowledge. Concerning the *content* of knowledge, we are providing support for people to analyze, model and reorganize the hospital logistic processes with the new knowledge that can be distilled from electronic patient records (EPR's) and from diagnosis treatment combinations (DTC). With respect to the *forms* (types) of knowledge, a classification consisting of sensory, coded and theoretical knowledge has been used, based on the ideas of Boisot [3] and using the insights of cognitive science [4]. *Sensory knowledge* is based on sensory experience; it is very difficult to code. *Coded knowledge* is a representation based on a conventional relation between the representation and that which is being referred

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to. Coded knowledge contains all types of signs or symbols, expressed either as texts, drawings, or mathematical formulas. A person who is able to explain why certain pieces of knowledge belong together possesses *theoretical knowledge* concerning this specific knowledge domain. Theoretical knowledge is often used to identify causal relations (i.e. if-then-relations).

Employing the knowledge categorization defined by van Heusden&Jorna [5] (i.e. sensory, coded and theoretical knowledge), we propose a KM perspective for redesigning a business process which consists of:

1. Knowledge creation. Raw data are first converted into coded knowledge, then this knowledge is used to provide theoretical knowledge about the logistic hospital process.
2. Knowledge use and transfer. New theoretical knowledge can be used for analyzing, diagnosing and reorganizing the logistic hospital process. Because of its codification, it can be easily transferred to other people, or from one part of the organization to another one.

The paper is organized as follows: in Section 2 we describe two forms of knowledge conversion and the creation of new knowledge about the treatment process in a hospital. In Section 3 we illustrate how newly created knowledge can be used to reorganize the hospital logistic process. We conclude our paper with directions for further research in Section 4.

2 Knowledge Conversion. New Knowledge About Patients

The number of patients who require the involvement of different specialisms is increasing because of the increasing specialization of doctors and an aging population. Special arrangements have emerged for these patients; however, the specialisms comprising these centers are based on the specialists' perceptions. In other words, specialists have a certain sensory knowledge about what specialisms should form a center, which eventually could be supported by some quantitative information (e.g. frequencies of visits), but knowledge expressed in models or rules is missing. Given some criteria for selecting patients, we use the records of 3603 patients from Elisabeth Hospital, Tilburg, The Netherlands. The collected data refer to personal characteristics (e.g. age, gender), policlinic visits, clinical admissions, visits to radiology and functional investigations.

Medical specialists need knowledge expressed in explicit models (i.e. theoretical knowledge) as a base for creating multi-disciplinary units, where different specialisms coordinate the treatment of specific groups of patients. However, the information existing in electronic patient records (EPR's) needs to be distilled in a meaningful way. We obtain the needed knowledge by converting (i) **raw data** into **coded knowledge** (RD⇒CK) and (ii) **coded knowledge** into **theoretical knowledge** (CK⇒TK).

2.1 The Development of Logistic Patient Groups

For the first type of conversion RD⇒CK, we use the idea of operationalizing the logistic complexity by distinguishing six aggregated logistic variables, developed in [6]. Theoretical knowledge provides knowledge expressed as causal and structural relations. This knowledge is necessary when taking decisions for re-organizing hospitals. For the second type of conversion CK⇒TK, we refer again to [6]. First, two valid clusters are identified: one cluster for "moderately complex" patients, and another cluster for "complex" ones. Second, a rule-based model is induced to characterize these clusters. As general characteristic, patients from the "moderately complex" cluster have visited up to three different specialists, while patients from the cluster "complex" have visited more than three different specialists [6].

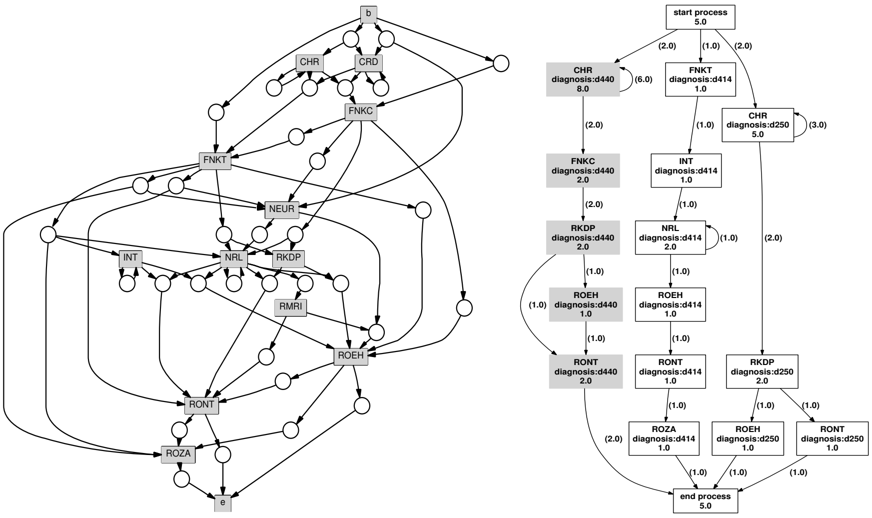
2.2 Discovering the Process Models for Patient Logistic Groups

Theoretical knowledge expressed in clear-cut patient logistic groups and their rule-based characterizations do not provide enough understanding and arguments for (re-)organizing multi-disciplinary units. To better understand the treatment process, we need insight into the logistic process model. Modelling an existing process is often providing a prescriptive model, that contains what "should" be done, rather than describing the actual process. A modelling method closer to reality is using the data collected at runtime, recorded in a process log, to derive a model explaining the events recorded. This activity is called *process discovery* (or *process mining*) (see [7]).

Employing the process discovery method using Petri net formalism, described in [8], we construct process models for patients from the "moderately complex" and "complex" cluster. Thus, we convert coded knowledge (the process executions recorded in the process logs) into theoretical knowledge. In Figure 1 (a) the discovered Petri net model using only medical cases from the cluster "moderately complex" is shown. On every possible path, at most three different specialisms are visited, e.g. "CHR, INT" or "CRD, NEUR, NRL" (the visits for functional investigations/radiology are not counted as specialisms)[1].

Using the process discovery method, we obtain insights into "aggregated" process models for the patients belonging to "moderately complex" and "complex" clusters. We want to be more patient-oriented, that is to obtain insights at the individual patient level. We obtain theoretical knowledge expressed as *instance graphs*, which is a graph where each node represents one log entry of a specific instance [9]. The advantage of this technique is that it can look at individual or at grouped patient instances. In Figure 1 (b) we construct the instance graph for a selection of 5 "moderately complex" patients (the instance graph has been produced with ProM software, version 1.7 [10]). Moreover, we can see the

[1] The node labels mean: CHR - surgery, CRD - cardiology, INT - internal medicine, NRL - neurology, NEUR - neurosurgery, FNKT (FNKC) - functional investigations. RONT (ROEH, RMRI, RKDP, ROZA) - radiology.



(a) (b)

Fig. 1. The discovered process models. The Petri net model for cluster "moderately complex"(a) patients. The instance graph for 5 patients in the "moderately complex" cluster (b)

hospital trajectory of patients with specific diagnoses. For example, in Figure 1 (b), we can inspect the path of patients with diagnosis "d440" - atherosclerosis.

3 Knowledge Use and Transfer

For a better coordination of patients within hospitals, new multi-disciplinary units have to be created, where different specialisms coordinate the treatment of specific groups of patients. According to our results, two units can be created: for "moderately complex" cases, a unit consisting of CHR, CRD, INT, NRL and NEUR would suffice. "Complex" cases need additional specialisms like OGH, LNG and ADI. The discovered process models show that both processes contain parallel tasks. When treating multi-disciplinary patients, many possible combinations of specialisms appear in the log, due to a complex diagnosis process. Without patient clustering, it would be difficult to distinguish between patients, which leads to unnecessary resource spending (e.g. for "moderately complex" cluster).

Concerning the content of knowledge, it is possible to analyze, model and reorganize the hospital logistic processes in combination with the knowledge that can be distilled from Electronic Patient Records (EPR) (concerning illnesses, treatments, pharmaceutics, medical histories) and from Diagnosis Treatment Combinations (DTC). DTC's are integrated in such a way that hospitals can predict within ranges how long a patient with a certain illness will remain in the hospital.

The first issue concerning knowledge types is that much sensory knowledge - or behavioral activities of doctors and nurses - of the medical domain has to be converted into coded knowledge. EPR's and DTC's are designed from theoretical knowledge about the medical domain. The integration of sensory and theoretical knowledge via codes continues, however with increasing resistance of the medical profession. The second issue concerns the distillation of sensory, coded and theoretical knowledge from EPR's and DTC's, which are about the medical domain, into sensory and theoretical knowledge of the logistic processes.

The already mentioned clustering within the logistic processes and the methodology we explained can be of help, but the transfer of sensory and theoretical knowledge from the one content domain to another completely different content domain is very difficult. On one hand, the knowledge that triggers important decisions should be transparent, understandable and easy to be checked by all involved parties; reorganizing an institution implies difficult decisions and high costs. Therefore, our approach provides robust theoretical knowledge of a highly abstract kind of the logistic hospital process. On the other hand, the newly developed coded and theoretical knowledge transferred to people, may even lead to a new development in behavior.

4 Conclusions and Further Research

In this paper we proposed a KM approach for redesigning a business process, by employing the knowledge categorization defined by van Heusden&Jorna [5]. Our strategy focuses on (i) knowledge creation and (ii) knowledge use and transfer. We illustrated our approach by considering the treatment process of multi-disciplinary patients, that require the involvement of different specialisms for their treatment. The problem is to provide knowledge for reorganizing the care for these patients, by creating new multidisciplinary units. First, we identified patients groups in need of multi-disciplinary care. The clustering of the complexity measures obtained by converting raw data into coded knowledge, resulted into new pieces of knowledge: two patient's clusters, "complex" and "moderately complex". Second, we found the relevant specialisms that will constitute the ingredients of the multi-disciplinary units. We converted coded knowledge into theoretical knowledge, by building instance graphs for a selection of "moderately complex" patients, and Petri net process models for the treatment of "complex" and "moderately complex" patients. This theoretical knowledge provides insights into the logistic process and supports the reorganization of the care process. Our approach is meant to be more patient-oriented, in the sense of reducing redundant and overlapping diagnostic activities, which will consequently decrease the time spent in the hospital and shorten the waiting lists.

As future research, we will concentrate on EPR and DTC. These kinds of data structures will give more possibilities to improve the logistic processes and can be used to inform the patient better about the medical issues and treatment sequences.

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